LARGE DOWNHOLE SEISMIC SENSOR ARRAY

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Since the days of the very first reflection seismic line acquired for petroleum exploration, geologists and geophysicists have wanted better quality reflection data and more resolution of the subsurface. As technology improved from single-channel analog recorders to multi-channel digital recording, so did the ability of explorers to find more reserves in shorter periods of time. Borehole seismic surveys started two decades ago with vertical seismic profiles (VSPs). However, despite their success, geophysicists continue to demand more from borehole surveys. In the mid-1980s, several research teams within the major companies designed and tested various systems of borehole seismic receivers and sources. Such surveys promised to allow companies to shoot from one well to another, thereby providing what amounted to a seismic "catscan" of the earth between the two wells. While potentially useful in exploration ventures, the real promise of these so-called cross-well surveys lies in their ability to image producing horizons within existing fields, thereby enabling production and injection strategies to be optimized. Unfortunately, cross-well surveys suffer from high data acquisition costs. Based on the experience of several operators active in the field, there is a direct correlation between the number of receivers one puts into the well bore and the cost of the survey. For cross well seismic to achieve its real potential, a major change in data-acquisition technology had to be found.

To solve this problem, the INEEL under a CRADA with OYO Geospace Instruments is developing a large downhole seismic sensor array (LDSSA) that can be scaled to >100 sensor locations (3-axis using either geophones or accelerometers) and can be clamped, unclamped, and moved to a new borehole location. Systems developed in this effort along with evolving

computational techniques will be able to collect and interpret data in ways that will greatly enhance the industries' capability to find and extract oil and gas.

This project will provide the oil and gas industry with a more economic, higher-fidelity, three- (or four-) component, subsurface, seismic survey system. Successful development of the LDSSA requires unconventional clamping and deployment technology and a downhole electronic architecture that is significantly different from approaches currently employed on available 5-12 sonde arrays. It is our objective to design, fabricate, and test various downhole prototype seismic sensor modules, compatible with a large downhole seismic sensor array. The developed hardware is compatible with state-of-the-art electronics and fiber-optic telemetry technologies.

The Idaho National Engineering and Environmental Laboratory is funded to develop prototype seismic sensor modules scalable to at least a 300-channel system. The modules will be deployable in vertical and deviated well bores using conventional wireline and/or coiled tubing. The array can contain 100 three-component sensors, and will quickly and verifiably clamp to well casing. The hardware contains state-of-the-art electronics and fiber-optic technologies. With this new tool, subsurface seismic data can be collected and transmitted to the surface in real time where it can be recorded and processed. This system will help industry more economically acquire high quality, high frequency, three-component subsurface seismic data.

To date, the INEEL has fabricated and tested prototype packer-type and magnetically clamped modules in the borehole environment. Upon final design and testing, packer-clamped modules will be fabricated and mated to OYO's new proprietary electronics that provides full 24-bit data acquisition. This advanced electronics design will enable the original goal of 100 levels to not only be met, but also exceeded. Currently, OYO is using this new system with a previous-generation receiver module to acquire data in several areas. Issues associated with co-deployment of packer-clamped systems with production tubing in place are also being examined. The final task in this project is the fabrication and testing of a fully integrated fieldable prototype system. This task will demonstrate deployment, clamping, and operation of acquisition and telemetry systems in an integrated manner.

Using an early prototype, OYO Geospace Instruments ran a cross-well survey for a major producer in New Mexico. The results included: improved borehole seismic resolution by 9 times, provided nearly 10 times more data in $1/50^{th}$ of the time, and helped replace a 10 BOPD well with a130 BOPD well. Getting more oil out of existing fields either by enhanced production techniques or producing previously unseen "new" reserves, borehole seismic surveys hold great promise for producers, majors and independents alike.

As the INEEL's CRADA partner, OYO Geospace Instruments has the first right-of-refusal to license any of the designs being created at the INEEL. As a manufacturer of geophysical instrumentation, OYO is in a position to build borehole systems to any service supplier who wants them.